SDSS-II Supernova Survey - Spectroscopy Analysis of 2005/2006

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Abstract

The SDSS-II Supernova Survey team have pursued extensive follow-up spectroscopy campaigns at a number of telescopes (especially HET, APO, WHT, Subaru, MDM, Keck, NTT and SALT). The observations to date (Fall 2006, 2006) have yielded spectra of several hundred SNe, focusing on type Ia's, but including classification spectra and synoptic monitoring of a variety of other supernova types, as well. The Ia data, in particular, allow us to explore the diversity of SN spectra and make connections with the SDSS-measured light curves. In our sample, dominated by supernovae at redshifts ~0.1-0.35, most spectra have significant contamination from the host galaxy, making host subtraction a critical step for the SN identification and subsequent spectral analysis. In this update, we describe spectral results from 2005 and 2006, emphasizing our efforts to improve host galaxy subtraction with PCA and chi-square fitting methods and describing some spectral diversity in the SN Ia sample.

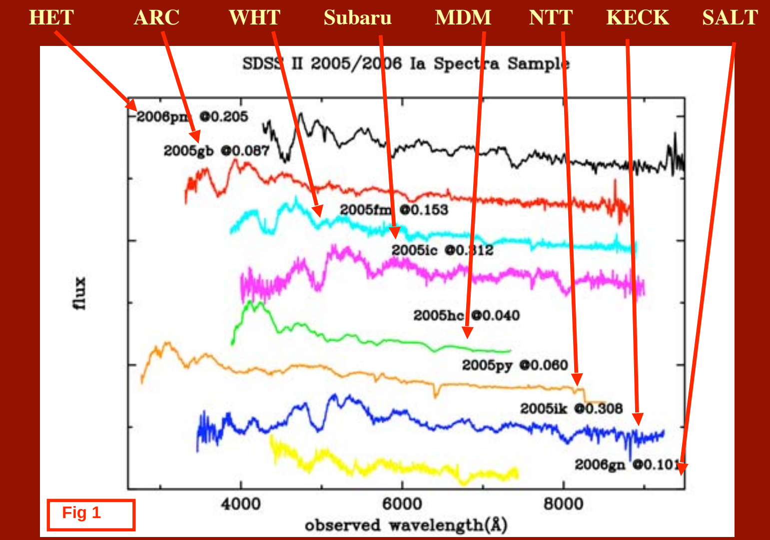

Fig 1

Host Contamination

Our SN spectra are often blended with the spectra of their host galaxies. Thus separating the SN and host galaxy light is critical for the SN identification and subsequent spectral analysis.

Fig 2: A sample of observed spectra with significant host contamination

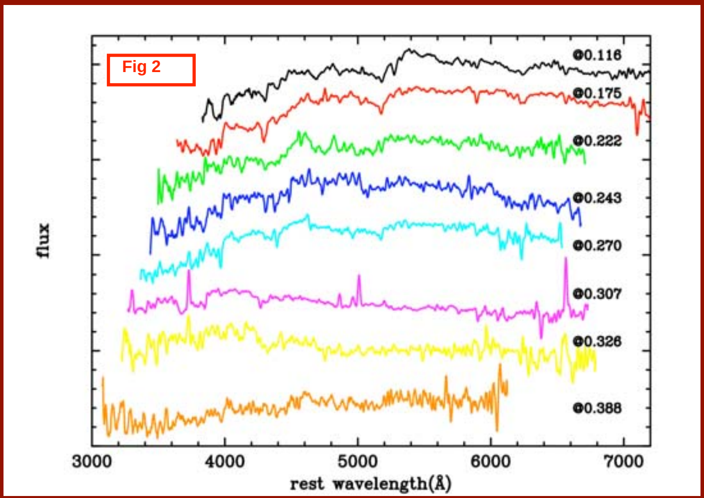

Fig 2

PCA & Chi-Square Fitting

To quantify the galaxy contamination and best isolate the supernova spectrum, we have explored two decomposition methods - PCA (Principal Component Analysis) and Chi-Square fitting.

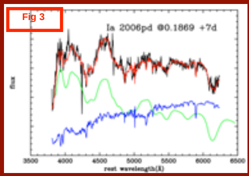

Fig 3

PCA (Fig 3)

We project the observed spectrum to an orthogonal set of "eigenspectra" constructed from SDSS galaxy templates and to a library of SN templates (*assumed* to be orthogonal to the galaxy eigenspectra) to quantify the relative contribution of host light (see Connolly et al. 1995, Madgwick et al. 2002, 2003; our code also modified by J. Estrada, FNAL).

Fig3-8: data, model, SN template, galaxy template

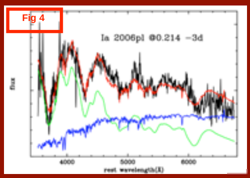

Fig 4

Chi-Square Fitting (Fig 4)

We define χ^2 as $\chi^2 = \frac{1}{(n-1)} \times \sum_{\lambda} \frac{(Data(\lambda) - a \times SNtemp(\lambda,z) - b \times Galtemp(\lambda,z))^2}{\sigma(\lambda)^2}$ where σ is the error on the spectrum and a, b are the fitting parameters for low extinction (see e.g. Howell 2005), for each redshift z.

We fit the spectrum with a series of models in (a,b,z) space for each possible combination of galaxy template and SN template and select the best SN and galaxy type, and redshift z.

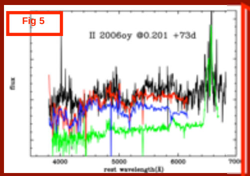

Fig 5

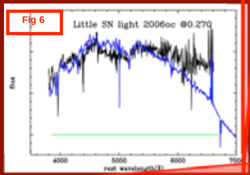

Fig 6

PCA vs Chi-Square

Since the assumption of the PCA method (host light orthogonal to SN light) is not accurate, PCA fails for some cases when the χ^2 fitting method still successfully identifies the SN type, phase and redshift. For example, PCA decomposition fails on 1/2 of the spectra in Fig 2. For comparison we list the χ^2-fit fraction of light from the SN (at 5500A rest) and the best-fit SN & galaxy types below:

[From Top to Bottom in Fig 2]

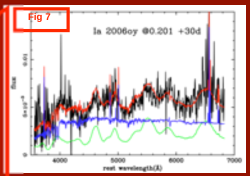

Fig 7

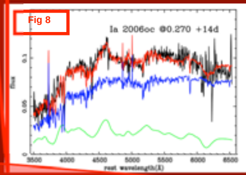

Fig 8

redshift	0.116	0.175	0.222	0.243	0.270	0.307	0.326	0.388
SN Type	Ia? (+22d)	Ia (+25d)	Ia (+18d)	Ia (+15d)	Ia (+15d)	Ia (+01d)	Ia (+04d)	Ia (+15d)
Galaxy Type	elliptical	elliptical	elliptical	elliptical	elliptical	sc	sc	s0
SN Fraction	0.20±0.04	0.20±0.01	0.48±0.07	0.43±0.05	0.24±0.03	0.29±0.05	0.4±0.2	0.26±0.06

SN Ia Spectroscopic Diversity

Measuring the diversity of spectroscopic features among Type Ia supernova (SN Ia) allows us to probe the nature of progenitor binary systems, study the explosion mechanisms and improve our understanding of SN Ia as cosmology distance indicators. We here test the potential use of χ^2 to flag spectra with significant departures from the best-fit standard 'Nugent' SN Ia models.

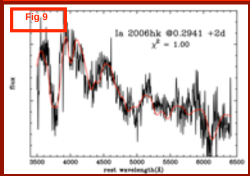

Fig 9

Below are three sample Ia spectra (host subtracted) with large χ^2 (Figs 10-12) compared to one with a smaller χ^2 (Fig 9).

The significance of the difference between data (black) and best-fit SN model (red) indicate spectroscopic diversity.

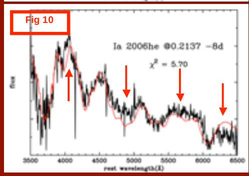

Fig 10

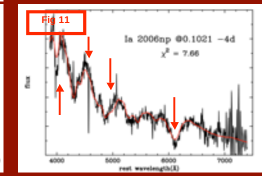

Fig 11

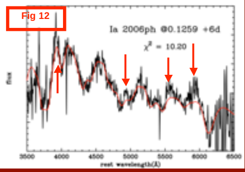

Fig 12

Future Work

- Embed the extinction analysis in our chi-square fitting procedure.
- Quantify the contribution of systematic effects to parameter errors.
- Use χ^2 measurements to identify spectroscopic diversity and compare spectroscopic signatures with light curves, color evolution and SN luminosity.